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Mobile Ad-Hoc Network (MANET) Method: Some Trends and Open Issues

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Abstract: This study analyzes the latest developments and trends in the field of Mobile Ad-Hoc Networks (MANET) through a bibliometric approach using a metadata dataset from publications taken from Scopus between 2021 and 2024. By utilizing VOSviewer to visualize the data, the study identified key keywords that dominated the MANET literature, such as "security", "routing protocols", "mobility", and "5G". The visualization results show several important clusters, including topics related to network security, vehicle networks (VANET), and the application of advanced technologies such as machine learning in network management. Despite the decline in the number of publications in 2023 and 2024, collaboration between authors continues to show a strong trend. The research also highlights various challenges that are still open problems, such as the development of efficient routing protocols, improving network security, and managing resources in a dynamic MANET environment. In addition to the VOSviewer analysis, further exploration was carried out using the built-in visualization tools from the Scopus web platform to enrich the interpretation of emerging topics and research connections. This was followed by a deeper conceptual mapping using Scopus AI, which provided a visual breakdown of interconnected themes such as security issues, routing protocols, and different network types like VANET and FANET. To complement and validate the findings, the study also incorporated evidence-based summaries retrieved from Consensus.app, offering additional insights from AI-driven scientific consensus. This multi-platform approach enhances the reliability of the analysis and provides a more comprehensive view of current and future research directions in the MANET domain.

Keywords: Bibliometrics; MANET; Scopus; Vosviewer; Visualization

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1. Introduction

This study discusses the latest developments of the Mobile Ad-Hoc Network (MANET) method through bibliometric analysis using metadata datasets from Scopus in the period 2021 to 2024. MANET is a dynamic, self-contained, wireless network that does not require fixed infrastructure, making it an essential solution for communication in situations such as disasters, military, and rural environments. As technology develops, the methods used in MANET continue to undergo innovation to improve network performance, security,

and communication efficiency. In this study, bibliometric analysis techniques were applied to map research trends and scientific developments in the field of MANET. The dataset collected from Scopus includes scientific publications from relevant journals, conferences, and other papers. The analysis process was carried out using VOSviewer software to visualize the relationship between keywords, collaboration between researchers, and publication patterns over the past four years. This analysis is expected to provide a comprehensive overview of current research focuses and identify areas of rapid growth [1], [2], [3].

The results of this bibliometric analysis show a significant increase in research related to routing protocols, network security, energy efficiency, and the application of MANET in IoT (Internet of Things) environments. Visualization with VOSviewer allows the identification of dominant research clusters as well as demonstrating global collaboration between institutions and researchers in this field. In addition, trends in technological developments such as integration with 5G networks and the implementation of artificial intelligence (AI) for network optimization are also in the main spotlight. This research also identifies several challenges that are still faced in the development of MANET, such as data security issues, network stability in dynamic conditions, and limited device resources. Through this analysis, recommendations for future research were prepared, including the exploration of hybrid routing methods, improved security using cutting-edge cryptography techniques, and the integration of MANET with future network technologies [4], [5], [6]. Figure 1 below contains an illustration of the Concept of MANET.

Figure 1. Concept of MANET

As such, the study makes an important contribution to researchers, technology developers, and policymakers in understanding MANET's developments and challenges. The results of this bibliometric analysis can be a strategic guide to direct MANET research

and development to be more effective in responding to the evolving needs of wireless communication in this digital era [7], [8], [9].

2. Methodology

The dataset used in this study was obtained from Scopus, one of the largest databases of abstracts and citations for academic literature covering a wide range of disciplines, including science, technology, medicine, social sciences, arts, and humanities. This dataset includes metadata of publications related to the Mobile Ad-Hoc Network (MANET) published between 2021 and 2024, with information such as document title, author, author affiliation, year of publication, number of citations, keywords, and cited references. The data collection process is carried out using the query: TITLE-ABS-KEY (mobile AND ad-hoc AND network) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024)), which ensures the results include a study of mobile networks that can form dynamic and self-sufficient connections without fixed infrastructure. Restrictions based on the year of publication (2021-2024) make the results more relevant to the latest research, covering the latest technological developments, challenges, and innovations related to MANET. This dataset is then downloaded in CSV format for easy further analysis [10], [11], [12].

The query is designed to filter out the latest publications relevant to the Mobile Ad-Hoc Network (MANET) in the period 2021 to 2024. After conducting a search, 4,685 documents were obtained which included journal articles, conference papers, and scientific reviews. The data is then exported in CSV format, which includes important information such as title, abstract, author, institution, keyword, and year of publication. The initial step of analysis is carried out by utilizing the standard visualization features provided by the Scopus web platform. This visualization includes the distribution of publications by year, document type, country of origin of the researcher, and the most frequently used keywords. Scopus' built-in visualization feature provides an early overview of research trends, the dominance of certain topics, and the geographic distribution of scientific contributions in the field of MANET. These results serve as a basis to understand the general research pattern before conducting a more in-depth analysis [13], [14], [15].

Furthermore, bibliometric analysis continued using the VOSviewer software to obtain more detailed and interactive visualization. The CSV data obtained from Scopus is imported into VOSviewer, and the mapping process is done based on keywords, citations, and author collaboration. This technique allows the identification of interrelated research clusters, relationships between topics, and the evolution of research trends in the period analyzed. Visualization with VOSviewer includes network visualization, overlay visualization, and density visualization to provide comprehensive insights. In the analysis using VOSviewer, various parameters are selected to ensure accurate and informative visualization results. One of them is determining the minimum number of keyword occurrences to filter out significant terms. In addition, co-occurrence analysis is used to see

how often two keywords appear together in a publication, so that the pattern of relationships between concepts can be clearly seen. Visualization of collaboration between researchers and institutions was also carried out to understand the dynamics of global cooperation in the field of MANET [16], [17], [18].

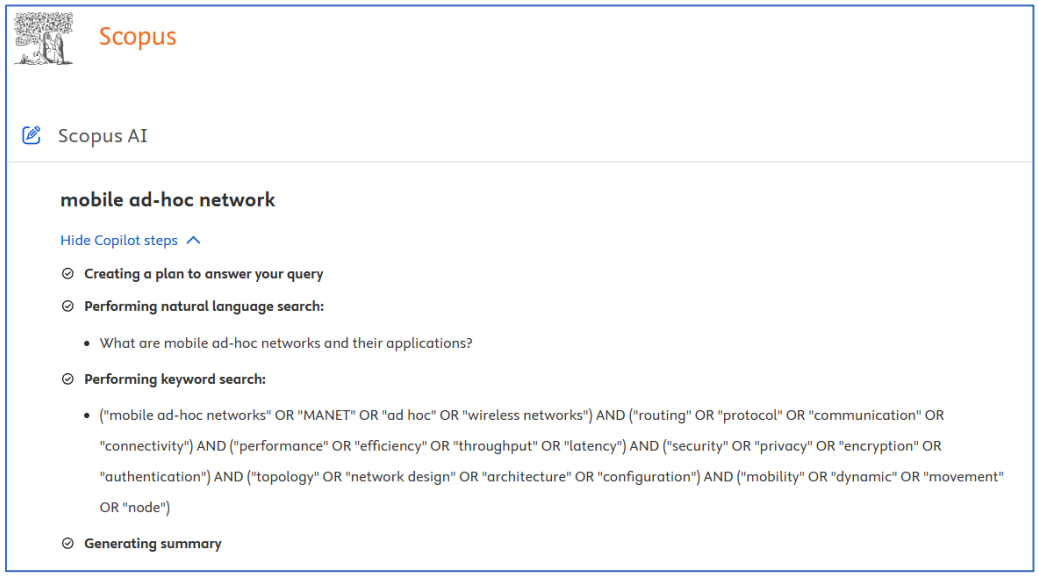


Figure 2. Copilot steps in Scopus-AI

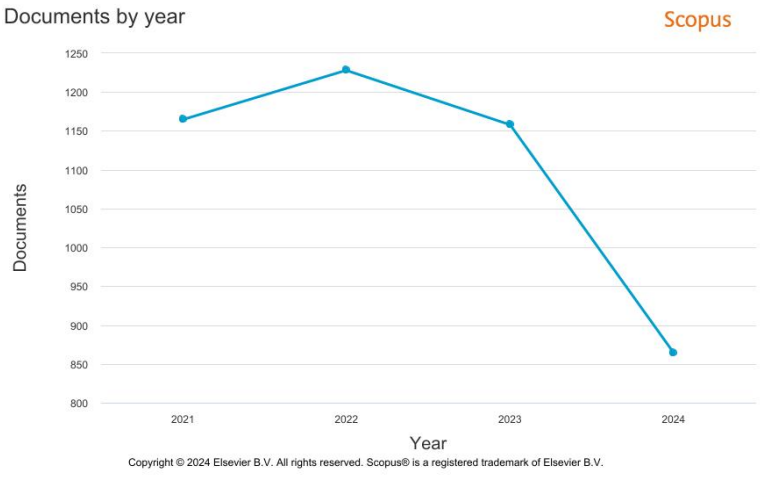
After processing the dataset obtained from the Scopus database using VOSviewer to identify key themes and research clusters, further analysis was conducted by examining the built-in visualizations available on the Scopus web platform. This was followed by an exploration using Scopus AI to generate a concept map highlighting the interconnections between core topics such as security issues, routing protocols, and types of networks within the Mobile Ad-Hoc Networks (MANETs) research domain. To enrich the analysis and gain broader insight, the findings were also cross-validated and expanded using results from Consensus.app, which provided AI-driven evidence-based summaries from scientific literature [19]. The results of this methodology provide an in-depth understanding of the development of MANET research over the past four years. The resulting visualization shows key topics, emerging research trends, and networks of collaboration between researchers. With a combination of preliminary analysis from Scopus and advanced mapping using VOSviewer, this study was able to provide a comprehensive picture that can be used as a basis for further studies or future MANET technology development policies [20], [21], [22]. Figure 2 contains information on Copilot steps in Scopus-AI.

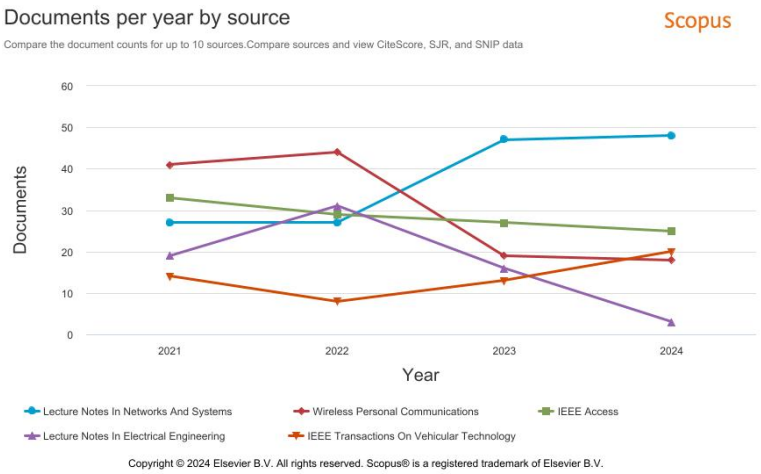
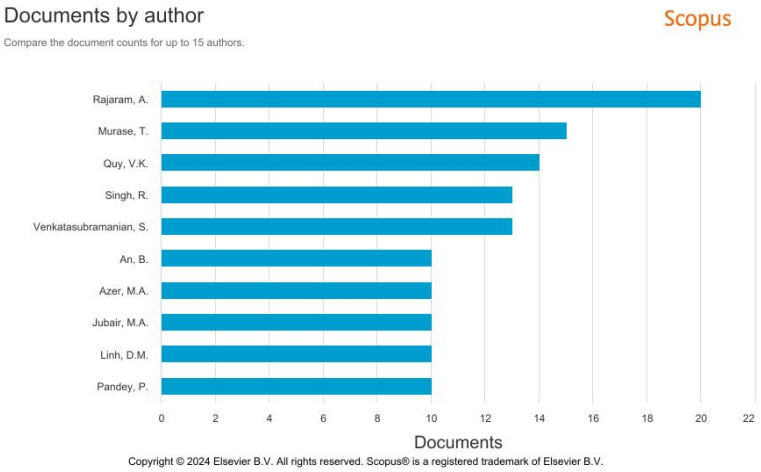
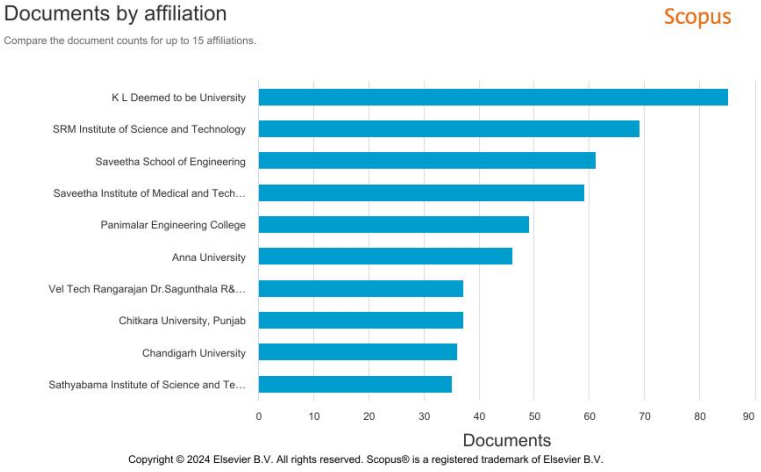
3. Results and Discussion

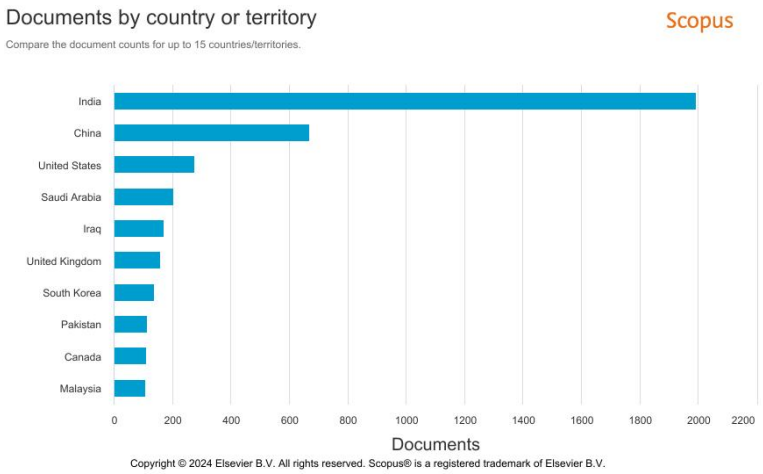
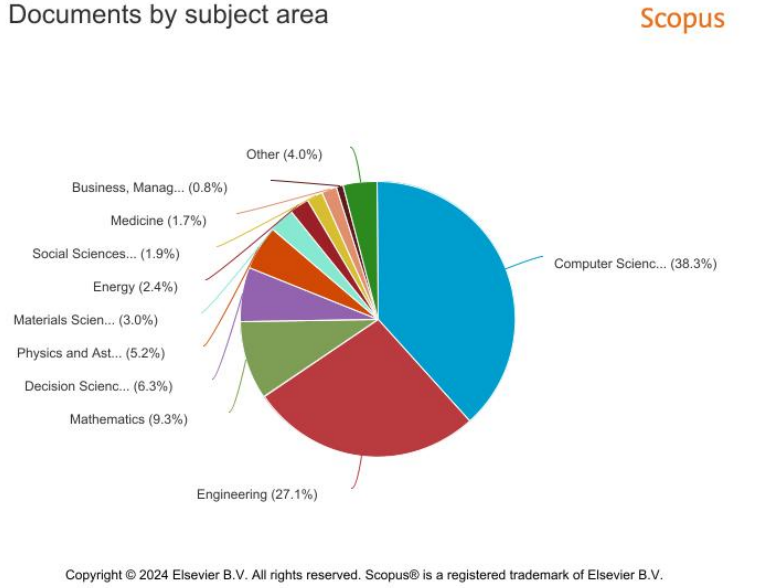
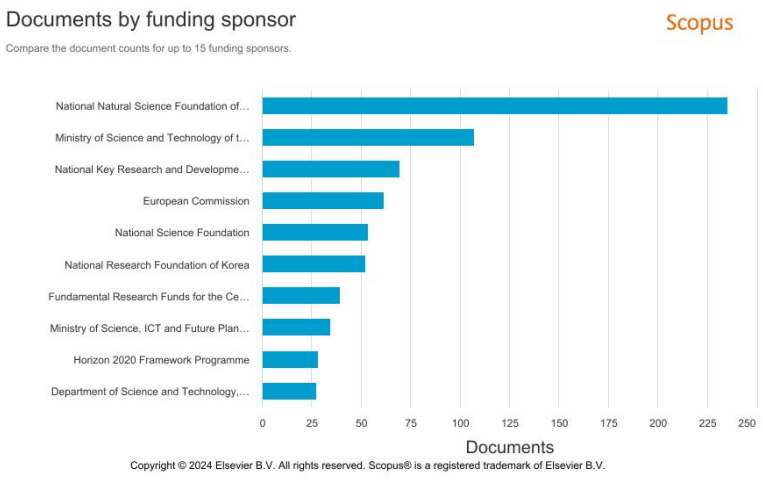
Applications in MANET bibliometric analysis include various types of analysis, such as co-authorship analysis to look at author collaboration networks, co-occurrence analysis to identify trends in research topics, and citation analysis to understand the influence of certain publications in MANET's field. In terms of counting methods, fractional counting is more suitable to get a proportional picture of the contributions of each author or institution, while full counting can be used to focus on the total number of collaborations or appearances. By using authors, organizations, and keywords as units of analysis, it is possible to obtain comprehensive insights into the parties involved in the MANET research, the origin of the institution, and the main topics being researched [23], [24].

Table 1 contains a list of some of the built-in visualizations available in Scopus Web, designed to help users analyze and understand research data effectively. These visualizations include a variety of tools such as publication trend graphs that illustrate the growth of research over time, a map of collaboration between countries or institutions, as well as a graph of author networks that show relationships between collaborators. In addition, there is a keyword analysis feature to identify key research topics, as well as citation charts to assess the influence of a particular publication. With this visualization, Scopus Web makes it easier for researchers to dig important insights from bibliometric data [25], [26], [27].

Table 1. Some built-in visualizations from Scopus Web

Component	**Visualization**
Scopus Analyze Year	

Scopus Analyze Source	
Scopus Analyze Author	
Scopus Analyze Affiliation	

Scopus Analyze Country	
Scopus Analyze Subject	
Scopus Analyze Funding Sponsor	

Here are the steps to use VOSviewer: first, set up and enter the dataset to be analyzed into VOSviewer. Next, select the appropriate type of analysis, such as co-authorship, co-occurrence, citation, or bibliographic coupling. After that, determine the counting method, whether to use full counting or fractional counting, depending on the purpose of the analysis. Then, select the relevant unit of analysis, such as authors, organizations, or keywords. Once all the parameters are defined, run the analysis to get the visualization results in the form of a network map or other graph. Details of each step and the results of the visualization can be seen in some of Figure 3 below [28], [29].

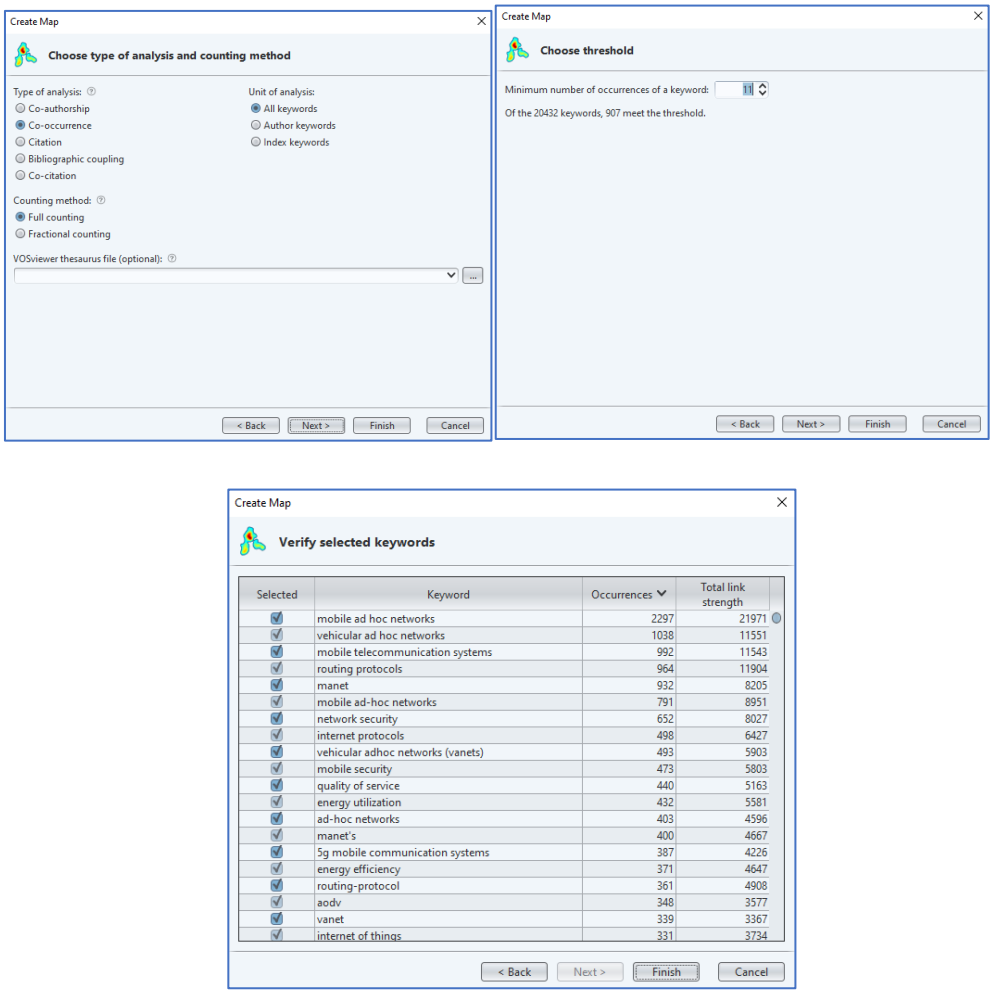


Figure 3. Steps to use Visviewer

Here are all the results of the visualization generated using the VOSviewer software, which displays the network of relationships between keywords based on several analyses of relevant studies. This visualization consists of multiple clusters identified through color differences, with each cluster representing an interrelated group of research topics or themes. The size of the circle describes the level of frequency of a keyword in the data, while the connecting lines and proximity between the circles reflect the co-emergence

relationship between keywords. These visualizations provide a comprehensive overview of the structure, trends, and key focuses within the research area, facilitating analysis of specific areas of study and identifying potential collaborations or further exploration of topics [30], [31].

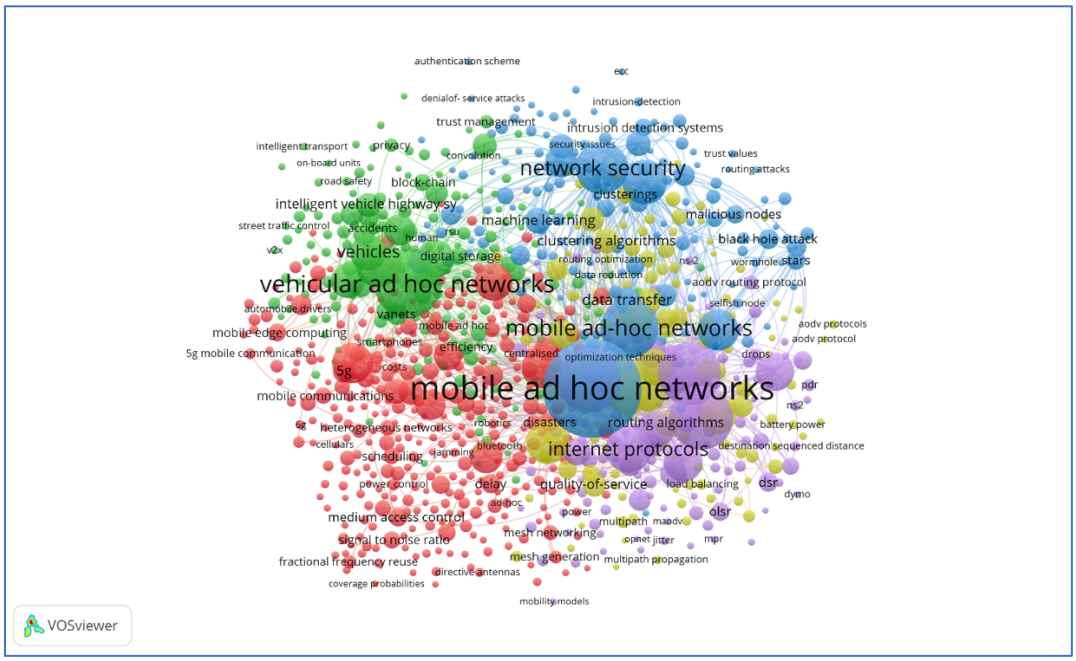


Figure 4. Visualization of Co-occurrenceence - All Keywords

The VOSviewer visualization in Figure 4 illustrates a bibliometric network map of research topics centered around “mobile ad hoc networks” (MANETs). Each node represents a keyword or term from scientific literature, where the size of the node indicates its frequency, and the lines between them reflect co-occurrence relationships. The term “mobile ad hoc networks” is positioned at the center, suggesting it is the primary focus across the dataset. Terms in proximity and connected by stronger links indicate more frequent joint appearances in the literature. The map is divided into color-coded clusters, each representing thematically related subfields within the broader research domain. The red cluster primarily focuses on vehicular communications and mobility-centric technologies, including “vehicular ad hoc networks,” “5G,” “mobile edge computing,” and “intelligent transport.” This reflects an increasing interest in integrating MANETs into intelligent transportation systems and modern mobile communication frameworks. The green cluster complements this by emphasizing applications related to smart highways, vehicle safety, and on-board units, signifying an alignment between MANET research and the development of intelligent vehicle ecosystems. Meanwhile, the blue and yellow clusters emphasize technical and security aspects of MANETs. The blue cluster covers “network

security," "intrusion detection," "trust management," and "machine learning," indicating active research addressing vulnerabilities in mobile networks. The yellow and purple clusters center on routing and optimization, with terms like "routing algorithms," "ad hoc on-demand distance vector," and "load balancing," which highlight the ongoing exploration of efficient data transmission methods. Collectively, this visualization reveals the diverse and interdisciplinary nature of MANET research, spanning from communication protocols and vehicular applications to cybersecurity and optimization techniques [7], [32].

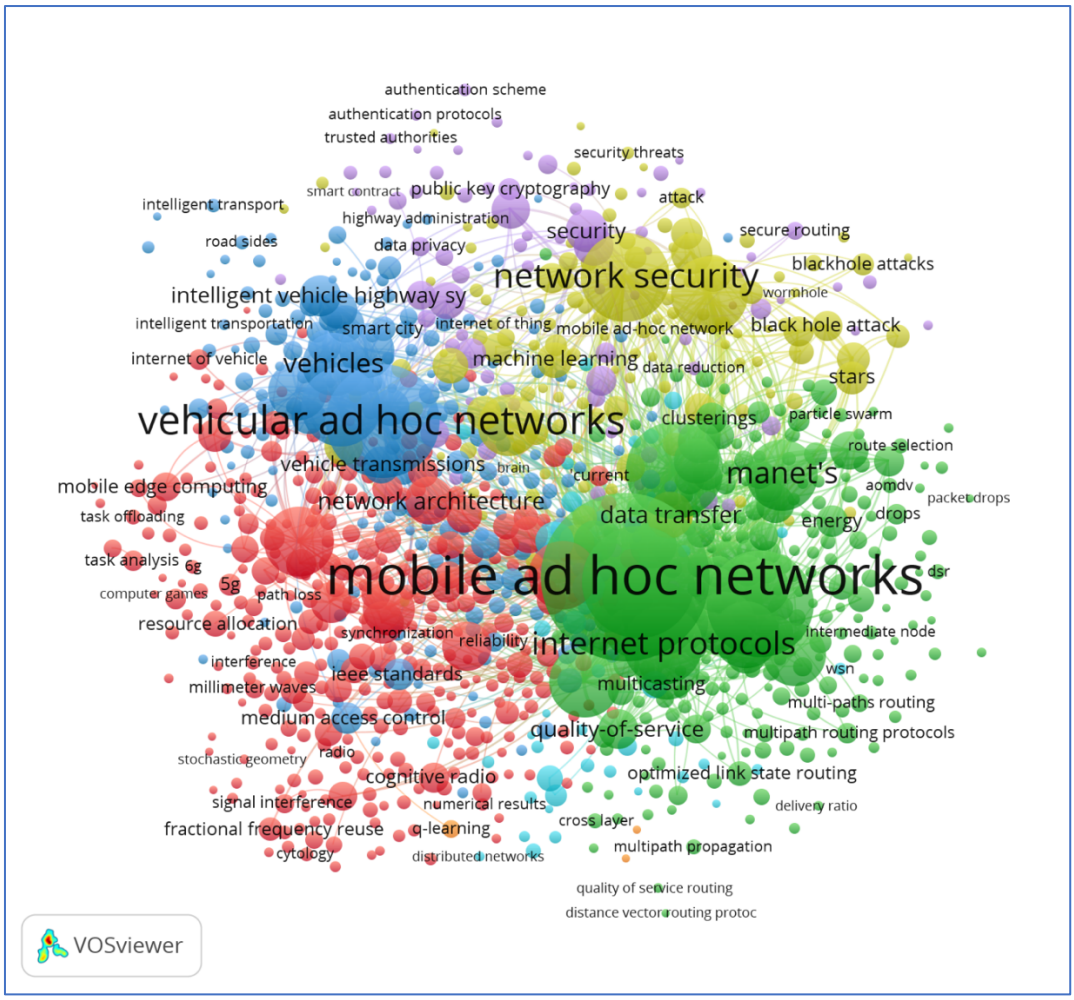


Figure 5. Visualization of Co-occurrence - index keywords

Figure 5. display a map of the keyword network in the research related to Mobile Ad-Hoc Networks (MANET) based on the publication dataset from 2021 to 2024. The keywords "mobile ad hoc networks" and "vehicular ad hoc networks" emerged as the main centers of the research, with large sizes indicating a high frequency of occurrence. The different colors indicate various research clusters, such as green clusters that focus on

internet protocols, data transfer, and routing protocols, as well as red clusters that highlight topics such as 5G, medium access control, and resource allocation. The blue cluster highlights the concepts of vehicular networks, intelligent transportation systems, and intelligent vehicle highway systems, while the purple cluster emphasizes aspects of network security and public key cryptography. The connecting lines between keywords indicate the degree of interconnectedness or co-occurrence, reflecting how these concepts are often researched together. This visualization provides in-depth insights into MANET's research focus and trends, as well as potential collaboration areas and ongoing challenges [16], [33].

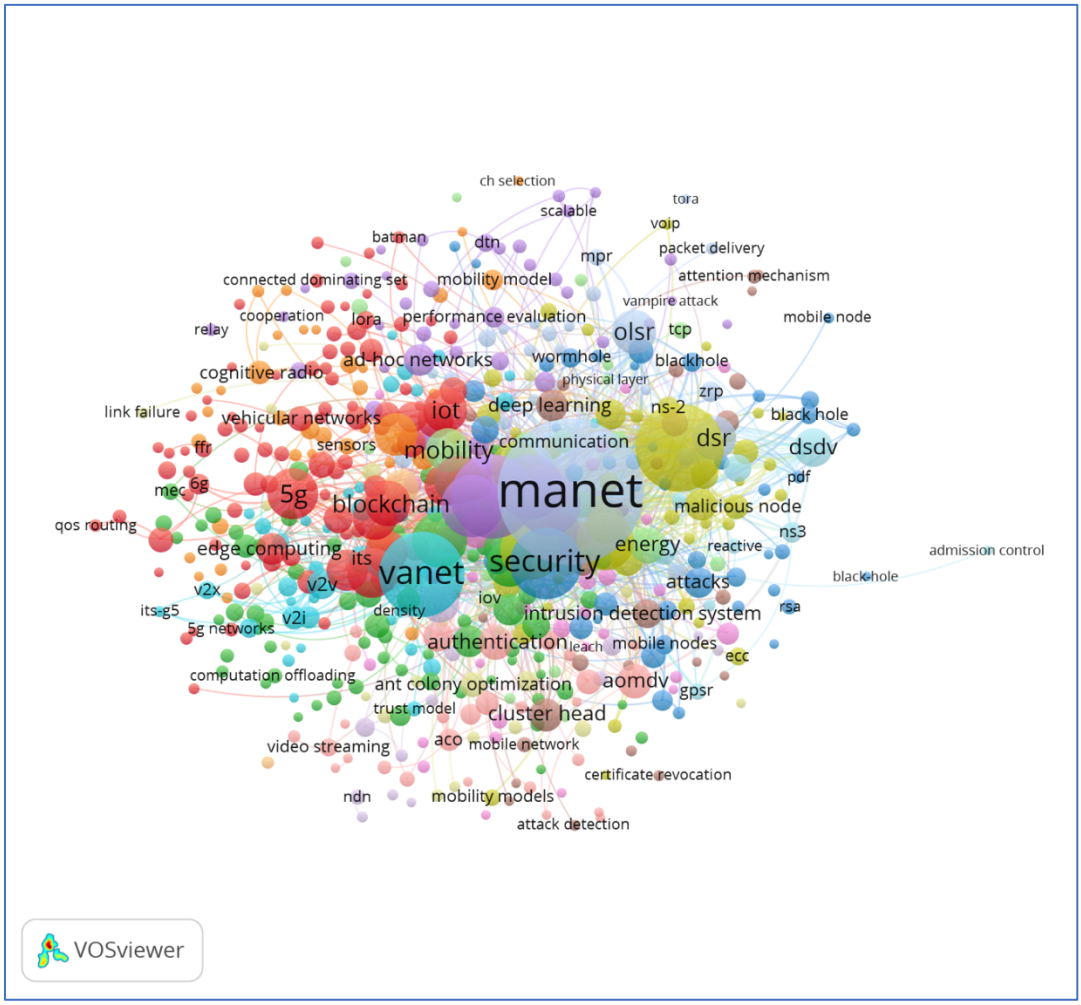


Figure 6. Visualization of Co-occurrence - Author Keyword

Figure 6. shows a bibliometric network map related to Mobile Ad-Hoc Network (MANET) research based on the most frequently published keywords between 2021 and 2024. Each point represents a keyword, where the size of the point describes the frequency with which it appears in the dataset. Key keywords such as "manet", "security", "vanet", and "mobility" emerged dominantly, indicating the research focus on aspects of security,

vehicle networks (VANET), and node movement within MANET. The different colors represent interrelated research clusters; for example, the red cluster shows the relationship between 5G technology, edge computing, and vehicular networks, while the green cluster is related to security and intrusion detection. The connecting lines between keywords describe the degree of co-occurrence, indicating concepts that are often researched together. These visualizations help understand research trends, emerging topics, and potential areas of collaboration in MANET studies [34], [35].

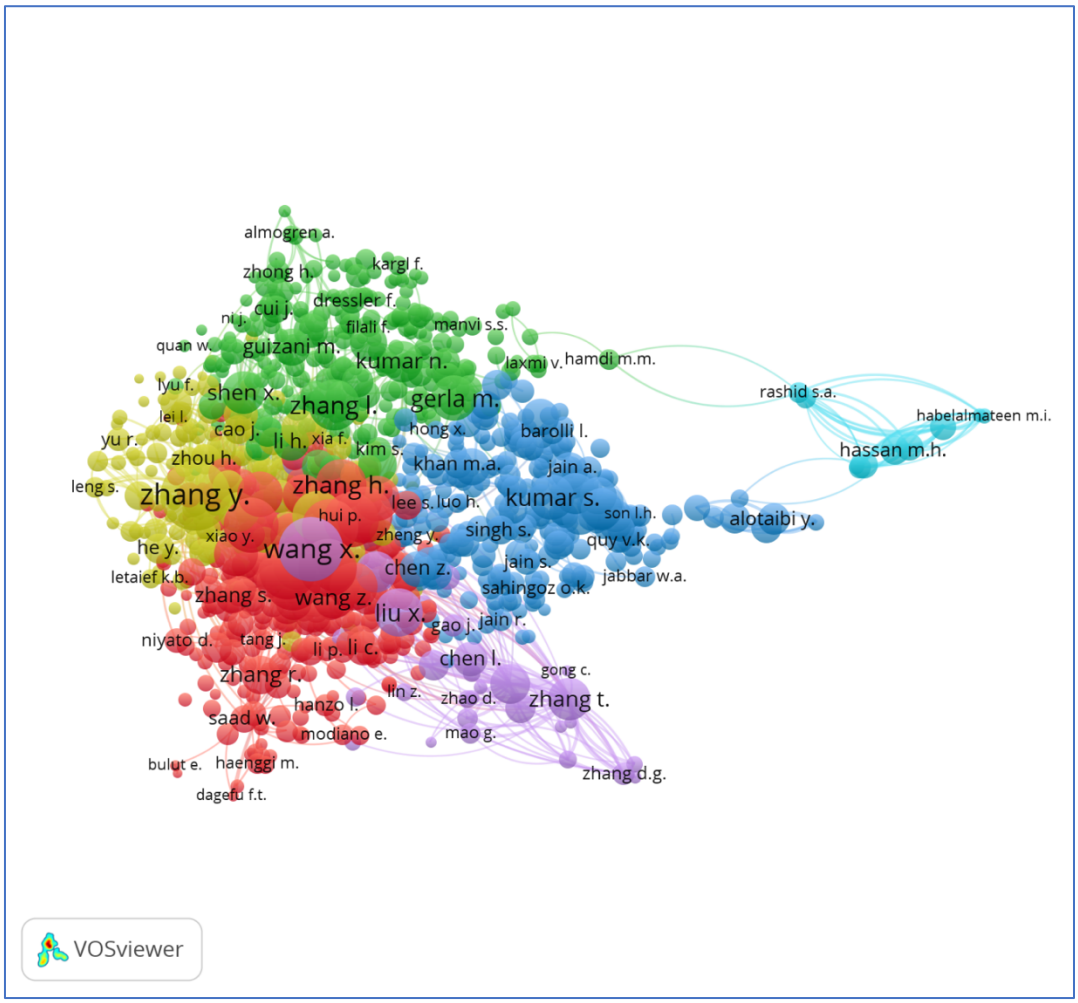


Figure 7. Visualization of Cocitation - Author

The VOSviewer visualization in Figure 7 represents a co-authorship network, where each node corresponds to an author involved in research related to a particular academic domain, likely mobile ad hoc networks based on context. The size of each node reflects the number of publications or the author's prominence, while the lines (or links) denote collaborative relationships between authors. The visualization is grouped into different colored clusters, each representing a group of closely connected authors who frequently collaborate. Central figures such as "Wang," "Zhang Y.," "Zhang H.," and "Kumar S."

indicate prolific contributors with widespread collaborations across multiple clusters. The spatial arrangement reveals collaboration patterns within the research community. The dense clustering in the left portion of the map suggests strong intra-group collaboration among authors, especially within the red, yellow, and green clusters. These clusters are tightly packed, showing intensive co-authorship, possibly from research institutions or regional collaborations. In contrast, the blue cluster, especially on the right-hand side with names like "Hassan M.H." and "Habelalmateen M.I.," appears more peripheral and loosely connected, suggesting either emerging authors or groups working in relative isolation or within niche topics. Overall, this visualization highlights the structure of scientific collaboration and the key players driving research in the domain [24], [36].

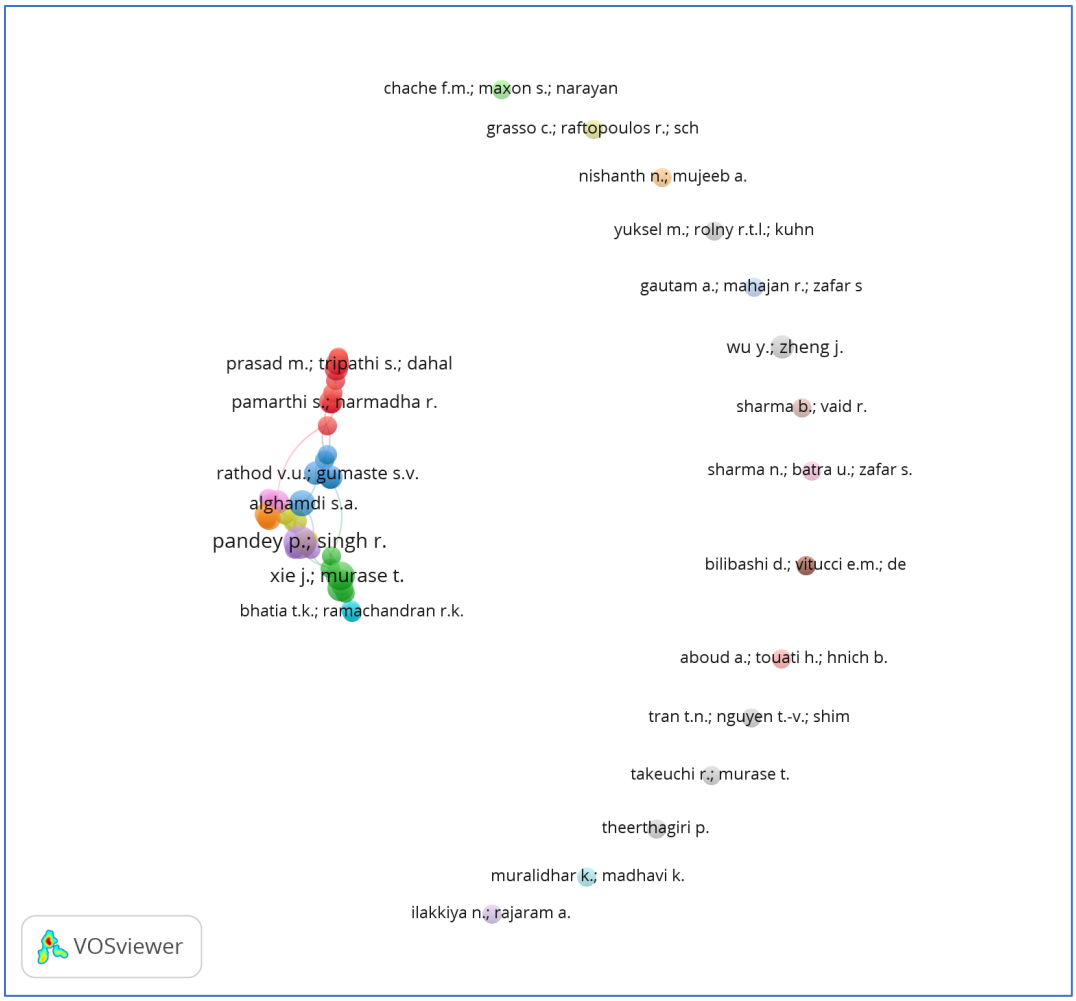


Figure 8. Visualization of Bibliographic Couping - Author

Figure 8 describes a bibliographic network based on couplings between authors using VOSviewer. In this graph, groups of authors are grouped based on their degree of similarity or bibliographic relationship, which is indicated by the color and proximity of the positions between the nodes. Authors such as Pandey P., Singh R., and Murase T. appear

to be in a dense group, suggesting a strong bibliographic connection. Meanwhile, some authors such as Chache F.M., Maxon S., and Narayan are more detached, reflecting weaker relationships or different specializations. The size of the text indicates the author's contribution or involvement in the network being analyzed [37], [38].

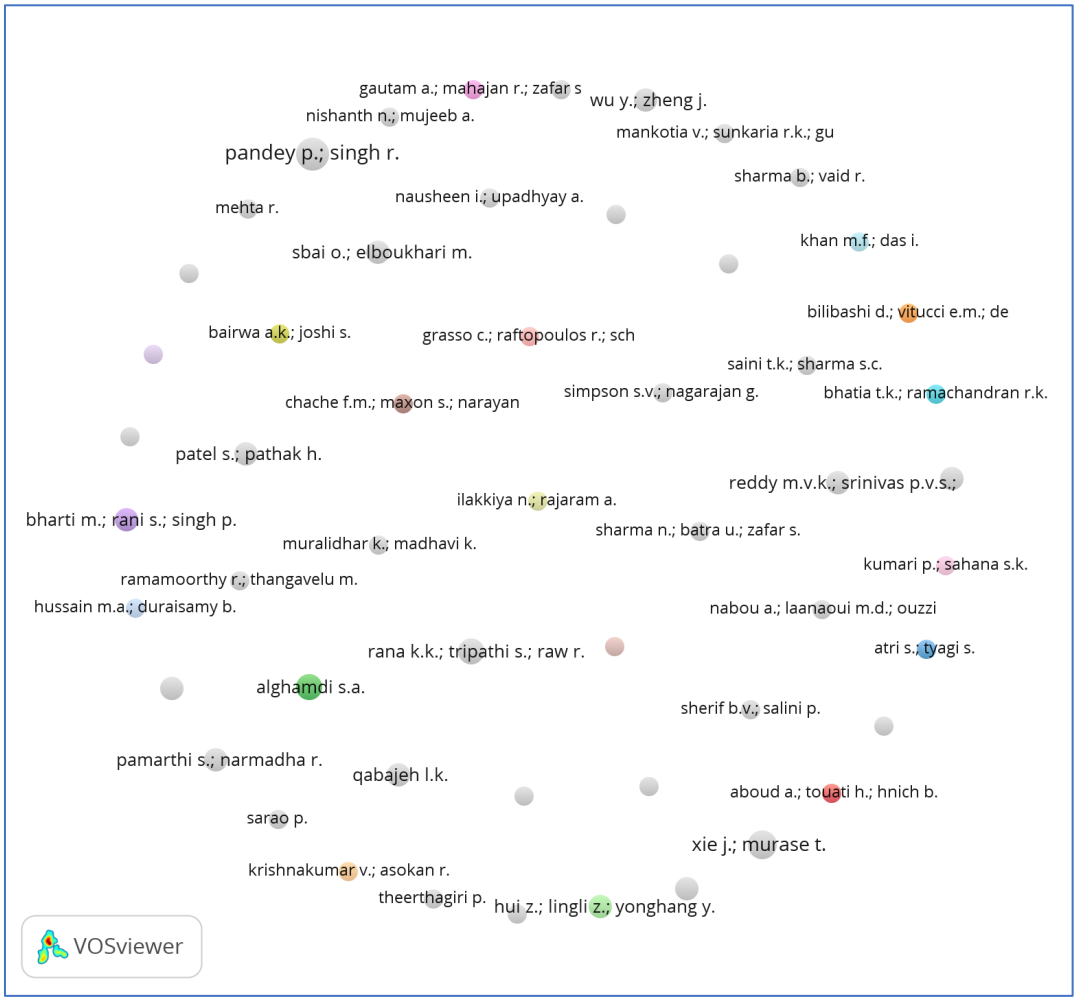


Figure 9. Visualization of Citation - Author

The VOSviewer visualization illustrates a co-authorship network characterized by sparse collaboration among researchers. Each node represents an individual author, while the distance and connectivity (or lack thereof) between nodes highlight the extent of their collaborative efforts. Unlike the previous dense networks, this visualization shows minimal interconnectedness, with most authors appearing as isolated or loosely associated entities. The relatively small node sizes and limited clustering indicate that these researchers are either early in their publication journey or are contributing independently without forming strong collaborative ties. A few minor clusters are visible, such as around authors like "Pandey P." and "Singh R.," who show some degree of co-authorship, but overall, the network lacks central figures or dominant collaborative groups. The scattered nature of the visualization implies that the topic under analysis

might be relatively new or niche, leading to fragmented contributions from various isolated researchers. Additionally, the low density suggests opportunities for increased collaboration and network formation in the future, especially if the field continues to grow and attract interdisciplinary research [39], [40].

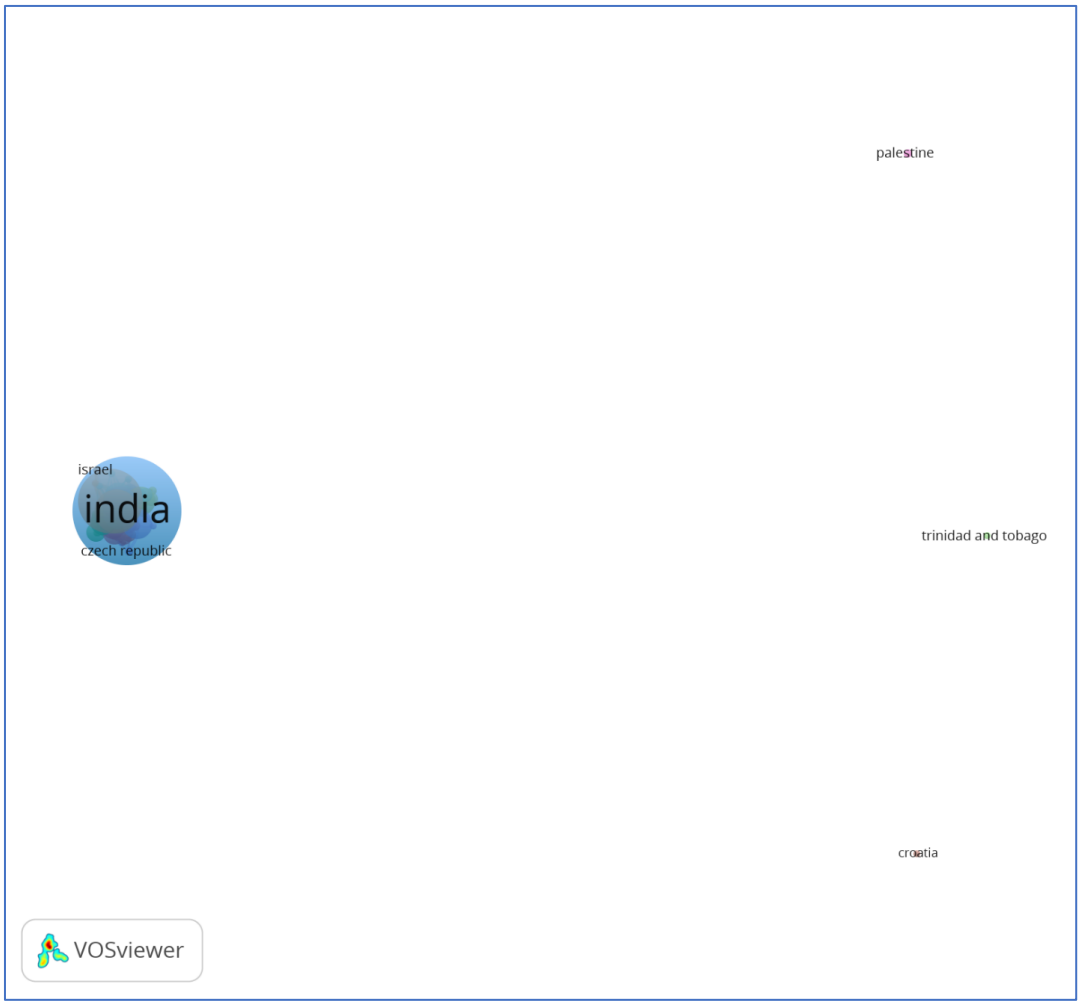


Figure 10. Visualization of Country

Figure 10 is a network map that displays relationships between countries using VOSviewer software. In this visualization, countries such as India, Israel, and the Czech Republic are seen to be in one closely interconnected group, indicated by their stacks in a circle. Meanwhile, countries such as Palestine, Trinidad and Tobago, and Croatia are separate, showing weaker ties or a lack of connection with the main group. The size and position of the text on this map reflect the level of involvement or connection of the country in the network being analyzed [41], [42]. Here's the comparison table of MANET routing protocols based on performance metrics and bibliometric impact (citations, trends, etc.).

Table 2. MANET routing protocols based on performance metrics and bibliometric impact

Routing Protocol	Type	Technical Performance	Citation Count / Trend (2021–2024)	Strengths	Weaknesses
AODV (Ad hoc On-Demand Distance Vector)	Reactive (On-Demand)	Low latency on active routes, energy-efficient	Very frequently cited (stable high trend)	Routes are created only when needed, saving bandwidth	Initial delay in route discovery
DSR (Dynamic Source Routing)	Reactive	Good for small networks; routing information carried in packet headers	Declining trend; still cited for high-density networks	No need for routing tables, highly adaptive	Header overhead increases in large networks
DSDV (Destination-Sequenced Distance-Vector)	Proactive (Table-driven)	Regular routing table updates; good stability	Less cited compared to AODV/DSR	Routes always available without initial delay	High control overhead even in low traffic
ZLR (Zone-based Location Routing)	Hybrid (Proactive + Reactive)	Optimized routing by dividing network into zones	Emerging trend; currently fewer citations	Efficient for large-scale MANETs	High implementation complexity
SPSR (Secure Path Selection Routing)	Proactive (Security-focused)	Emphasizes secure routing; tolerant to attacks	Emerging (trend rising but minor)	Secure against route manipulation attacks	Cryptographic processing overhead
ARIADNE	Secure Reactive	End-to-end authentication using symmetric keys	Moderate; often referenced in security research	Protects against various routing attacks	Requires accurate time synchronization
SAODV (Secure AODV)	Secure Reactive	Strengthens AODV against attacks (with digital signatures)	Rising trend in security-related studies	Resilient to blackhole/wormhole attacks	Digital signature adds computational load
MOSAODV (Modified SAODV)	Enhanced Secure Routing	Optimization of SAODV; faster packet delivery	Very recent topic, few citations yet (niche area)	Minimizes delay and overhead	More complex than standard SAODV

This study provides a detailed bibliometric overview of research trends in the field of Mobile Ad-Hoc Networks (MANET) from 2021 to 2024. Using data visualization tools

such as VOSviewer and Scopus, key aspects of MANET research were identified, including the most frequently occurring keywords, the most active authors, and the country's leading contributions to the field. Table 3 highlights the dominant research topics and technological focuses, such as security, mobility, and integration with emerging technologies like 5G. Table 4 presents the authors with the highest collaboration and publication activity, showcasing key figures who are driving advancements in MANET studies. Meanwhile, Table 5 illustrates the geographical distribution of research efforts, emphasizing the countries that have made significant contributions to MANET development. Together, these tables offer a comprehensive snapshot of the global research landscape surrounding MANETs [38], [42], [43].

Table 3. Top 10 Keywords in MANET Research (2021–2024)

Rank	Keyword	Frequency Level
1	mobile ad hoc networks	Very High
2	security	High
3	vehicular ad hoc networks (VANET)	High
4	mobility	High
5	5G	Medium-High
6	network security	Medium-High
7	intrusion detection	Medium
8	routing algorithms	Medium
9	load balancing	Medium
10	edge computing	Medium

Table 4. Top 10 Authors by Publication or Collaboration

Rank	Author Name	Collaboration/Citation Notes
1	Wang	Very Active
2	Zhang Y.	Very Active
3	Zhang H.	Very Active
4	Kumar S.	Active
5	Hassan M.H.	Moderately Active
6	Habelalmateen M.I.	Moderately Active
7	Pandey P.	Active
8	Singh R.	Active
9	Murase T.	Active
10	Chache F.M.	Moderately Involved

Table 5. Top 10 Countries by Research Involvement

Rank	Country	Notes
1	India	Highly Dominant
2	Israel	Dominant
3	Czech Republic	Dominant
4	Palestine	Moderate
5	Trinidad and Tobago	Moderate
6	Croatia	Moderate

Rank	Country	Notes
7	China	Highly Contributing
8	United States (USA)	Highly Contributing
9	Malaysia	Fairly Contributing
10	Pakistan	Fairly Contributing

Additional studies from consensus.app are as follows [44]. Mobile Ad Hoc Networks (MANETs) are decentralized, self-organized wireless networks where devices communicate without relying on fixed infrastructure. Their dynamic topology presents unique challenges in network configuration, routing, and security. Traditional methods like DHCP are unsuitable due to the distributed nature of MANETs, prompting the development of novel approaches such as extended IPv6 stateless autoconfiguration and binary split methods for IP allocation. These strategies address issues like network partitioning and merging. Routing is equally complex, with protocols like DSDV (proactive), DSR and AODV (reactive), and secure versions such as SAODV and ARIANDE being designed to adapt to frequent topological changes. Among them, DSR performs well in high-density networks, while ARIANDE shows strength in securing communication [45], [46].

Security and Quality of Service (QoS) are critical concerns in MANETs. Their open nature makes them vulnerable to attacks like blackholes, leading to the development of enhanced protocols such as MOSAODV, which strengthens AODV by improving packet delivery with minimal delay and overhead. Other innovative solutions include cellular automata for node authentication and secure transmission. On the QoS front, ensuring stable performance is difficult without centralized control, making admission control essential to manage bandwidth and session allocation. Techniques like HELLO packet advertisements and channel state differentiation have been proposed for better resource estimation. Simulation tools play a key role in testing these solutions—while NS-3 supports heterogeneous MANET environments, newer platforms incorporating SDN devices are helping researchers explore even broader scenarios. As MANETs continue to evolve, ongoing research is essential to develop robust, adaptive, and secure communication protocols for increasingly mobile and decentralized environments [47], [48].

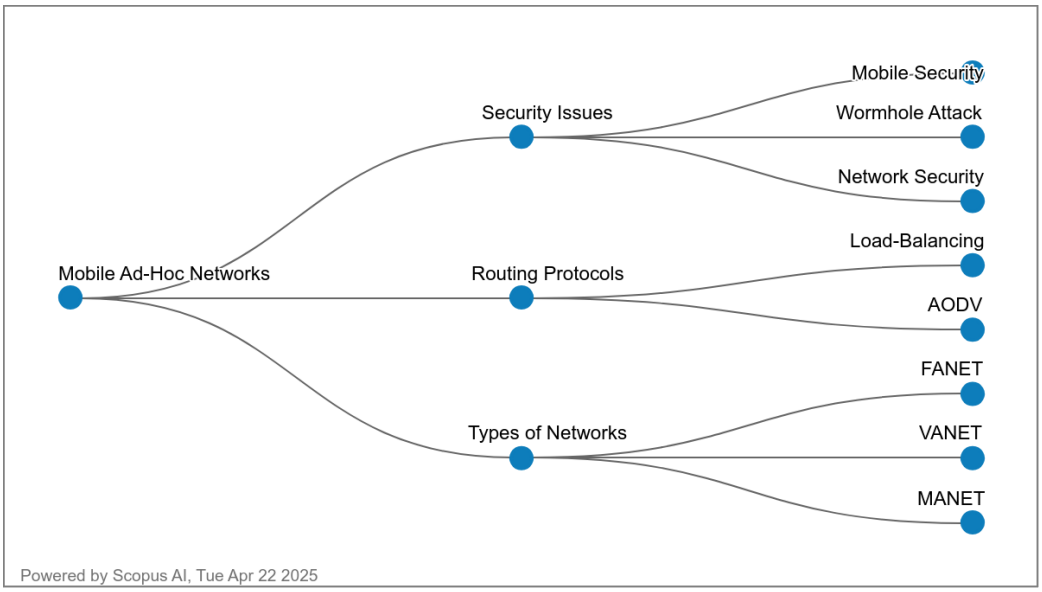


Figure 11. Concept map from Scopus AI [49]

The results of the study from Scopus-AI are as follows [50]. A Mobile Ad-Hoc Network (MANET) is a decentralized, self-configuring wireless network that operates without fixed infrastructure or centralized administration. Key characteristics of MANETs include dynamic topology due to node mobility, multi-hop communication where nodes relay data for one another, and support for heterogeneous devices such as laptops, smartphones, and sensors. These networks are especially useful in scenarios like emergency and disaster response, military operations, and civilian applications such as mobile classrooms and personal networking. Routing protocols commonly used in MANETs include AODV, DSR, DSDV, ZLR, and SPSR, each offering different strategies to manage communication in dynamic environments [51], [52]. Despite their flexibility and wide range of applications, MANETs face significant challenges, particularly in terms of security and technical constraints. Their open architecture and rapidly changing topology make them vulnerable to various attacks and complicated the maintenance of secure routes. Additionally, limited resources such as battery life and processing power pose operational challenges. Solutions to these issues include multi-fence security frameworks, cluster-based security schemes, and multi-path routing techniques aimed at improving data confidentiality and reliability. Overall, MANETs present a robust networking solution in infrastructure-less settings, but ongoing research is necessary to address their routing, security, and scalability issues [53], [54].

The diagram generated by Scopus AI in Figure 11 presents a conceptual map of research themes related to Mobile Ad-Hoc Networks (MANETs). It categorizes the main areas of scholarly focus into three major branches: Security Issues, Routing Protocols, and Types of Networks. Under "Security Issues," key topics include Mobile Security, Wormhole Attack, and Network Security, indicating an emphasis on the vulnerabilities and

threats faced by MANETs and the need for robust protective measures. This branch reflects ongoing research into safeguarding data transmission and preventing malicious activities within the network [55]. The "Routing Protocols" section highlights specific strategies for managing data flow in MANETs, such as AODV (Ad hoc On-Demand Distance Vector) and concepts like Load-Balancing, which are essential for efficient and reliable communication. The "Types of Networks" branch further classifies ad-hoc networks into subtypes like FANET (Flying Ad Hoc Networks), VANET (Vehicular Ad Hoc Networks), and MANET, suggesting diversification in the application of ad-hoc network models based on mobility environments (air, land, etc.). Overall, this visualization helps illustrate the multidimensional research landscape surrounding MANETs, encompassing both technical and security challenges as well as application-specific developments [46], [56].

Conclusion

The conclusions of this bibliometric analysis show that research on Mobile Ad-Hoc Networks (MANET) fluctuated in the period 2021 to 2024, with a significant decrease in the number of publications from 2022 to 2024. Despite the decline in the number of publications, the topics covered remain relevant and include technical, security, and application aspects of MANET in various fields. The visualization generated through VOSviewer shows the dominance of keywords such as "MANET", "security", "vanet", and "mobility", indicating a major focus on the development of security solutions, vehicle connectivity, and dynamic movement within the network. The clustering seen in the keyword network map illustrates the interconnectedness between various topics, such as 5G, edge computing, and vehicle networks, as well as security aspects such as intrusion detection and attack detection. The authors' collaborative analysis shows that there is a strong interaction between different groups of scientists who focus their research on the latest technological innovations and the challenges faced in the implementation of MANET. Overall, despite the decline in the number of publications from 2022 to 2024, the study still highlights key trends in MANET research involving the development of more efficient routing protocols, the implementation of machine learning, and improvements in service quality and network security. The collaboration between authors identified in the collaboration visualization shows that there is significant synergy between researchers from different institutions around the world, which accelerates progress in this field. By leveraging VOSviewer for bibliometric mapping, the study provides deeper insights into current research developments, dominating topics, and areas that require further attention, especially in the face of complex technical and security challenges in real-world MANET applications. To strengthen the paper’s conceptual contribution, we have identified several underexplored areas in MANET research, such as the development of AI-driven hybrid routing protocols and blockchain-based security mechanisms. Additionally, we propose a new conceptual framework classifying MANET research into three

major domains: routing optimization, resource management, and network security enhancement. This framework aims to map current research focuses and highlight new directions for future technological innovations in MANETs.

Although research on Mobile Ad-Hoc Networks (MANET) continues to grow, there are still some open problems that need to be addressed to advance this field. One of the key challenges is improving the efficiency and scalability of routing protocols in dynamic and resource-constrained network conditions. In addition, security issues, such as protection against blackhole, wormholes, and sybil attacks, are still major issues that hinder the implementation of MANET in the real world, especially in critical applications such as vehicle communications or the Internet of Things (IoT). The use of new technologies such as machine learning and 5G offers potential solutions, but the integration and application of these technologies in highly dynamic networks and without fixed infrastructure still requires further research. On the other hand, the management of resources, such as energy and bandwidth, as well as the implementation of more efficient network management in high-density environments, are also issues that need more attention in future research.

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